COSMOLOGY

Feeding the beast

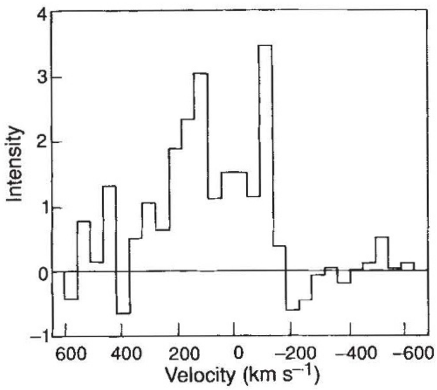
David Sanders

THE exceptionally luminous and distant infrared galaxy IRAS 10214+4724 is again in the headlines, this time following the discovery a few months ago that it harbours an enormous quantity of star-forming molecular gas as indicated by the detection of submillimetre emission from carbon monoxide gas. On page 318 of this issue[1], Solomon, Radford and Downes speculate on the nature of the energy source in 10214+4724, and discuss the implications of the CO detection in the context of nearer ultraluminous infrared galaxies. The authors calculate that the total mass of molecular gas is equal to 2–6 × 10^{11} solar masses, comparable with the total mass of stars in large nearby spiral galaxies. They speculate that the gas mass is a large fraction of the total mass of 10214+4724, as much as 90 per cent, and suggest that the term primaeval best fits this object, as it has only just begun the process of converting its initial mass of gas into stars.

The discovery of the high-redshift IRAS galaxy was reported in *Nature* last year by Rowan-Robinson *et al.*[2] and was the subject of an accompanying News and Views article[3] which framed the initial debate on the nature of this exceptionally luminous beast — hidden quasar or protogalaxy? The enormous infrared luminosity, equivalent to that of 3 × 10^{14} Suns or approximately 30,000 times the total luminosity of the Milky Way, makes this object a rival to the most luminous quasars. Although quasars emit mostly at optical, ultraviolet and X-ray wavelengths, they provide a plausible energy source for the exceptional luminosity of 10214+4724, and one need only invoke a heavy dust shroud to convert the short-wavelength radiation to the longer wavelengths characteristic of the thermal infrared.

The fact that 10214+4724 rivals the luminosity of the most luminous quasars is made more palatable given that we see it at an epoch when the number density of quasars peaks[4] and the most luminous objects are more likely to be found. However, another possibility for explaining the luminosity of 10214+4724 comes from exploring the implications of the large amount of dust that is needed to produce the observed infared emission. Rowan-Robinson *et al.* estimate the presence of 4×10^{8}–10^{10} solar masses of dust, depending largely on the shape of the still unmeasured submillimetre spectrum at wavelengths longer than 100 micrometres. Taking the upper end of this range, and assuming a gas-to-dust ratio of 100 — typical of normal spiral galaxies — the galaxy's total gas mass could easily be in the range 10^{11}–10^{12} solar masses, equivalent to the total mass (primarily in stars) of nearby large spiral galaxies. If the gas is primarily in the star-forming molecular phase then it would be conceivable that it is feeding a super burst of star formation that is the primary power source.

Of course, all the speculation concerning the nature of the energy source in 10214+4724 could have been for naught if the source had been incorrectly identified; the original paper[2] seemed convincing, but the high-redshift (z=2.286) source identified with 10214+4724 was actually just outside the IRAS position error ellipse, and one could have argued that the infrared emission had nothing to do with the distant source. However, any such notion quickly evaporated with the announcement by Brown and Vanden Bout[5] of the detection of an emission line (see figure) from the (3→2) rotational transition of the CO molecule at a redshift of 2.2867 corresponding to the reported optical redshift of 10214+4724.



Spectrum of CO (3→2) emission reported by Brown and Vanden Bout[5]. The detection required 17 hours of integration at the NRAO 12-metre telescope (Kitt Peak). The velocity scale corresponds to gas motion in the object rest frame. The observed centre frequency at zero velocity was 105.2331 GHz corresponding to the CO(3→2) rest frequency (345.7959 GHz) redshifted by (1+z=3.2867).

Although CO emission has become a standard method of determining the mass of molecular gas in galaxies, Brown and Vanden Bout's detection was shocking — the redshift exceeded the largest previously reported CO emission-line redshift by more than a factor of 10, and at first glance the emission was unexpectedly strong, implying the presence of an enormous quantity of molecular gas.

Solomon, Radford and Downes, in this issue, use the CO luminosity to compute a molecular gas mass of 3–6 × 10^{11} solar masses. They point out that the object's relative infrared and molecular gas properties closely resemble those of nearer ultraluminous infrared galaxies[6], and note that the choice between starburst and quasar models for its primary luminosity source parallels the debate over luminous infrared galaxies and quasars in the local Universe. But they still leave the question open.

My own view is that in this galaxy and in nearer ultraluminous infrared galaxies, luminous starbursts and quasar activity are triggered together when gas-rich galaxies come close together or even merge. In this picture, the peak in the quasar space density distribution near a redshift of 2 corresponds to the epoch when mergers of extremely rich disk galaxies are frequent. Each merger results in vast quantities of molecular gas being drawn into the merger nucleus, where it fuels a super starburst; the stars and gas then build or fuel the quasar nucleus.

The infrared phase is then plausibly the initial stage of this process, which eventually gives way to a phase of excess optical and ultraviolet emission as the dust shroud is driven away to reveal the nuclear engine. Star formation and disk building presumably began at an even earlier epoch, in which was created the substantial quantity of dust seen in 10214+4724.

Further studies of the object should provide additional fuel for the debate about starbursts and quasars. Draper *et al.*[7] report that the integrated optical light is strongly polarized (16±2 per cent) for an unresolved object, consistent with the hidden-quasar interpretation; and Soifer *et al.*[8] report that the equivalent width of the hydrogen emission line (Hα) is consistent with the largest values found in quasars. But the presence of 3–6 × 10^{11} solar masses of star-forming molecular gas would seem to provide sufficient fuel for those who favour the starburst model. The discovery of additional similar objects would certainly help, but for that we will have to await the more sensitive Infrared Space Observatory mission scheduled for early 1994. □

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